Transmission Bus Load Model – the Bridge for Cross-Cutting Information Exchange between Distribution and Transmission Domains

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Interrelationships between Operations of Transmission and Active Distribution Networks

- The transmission operations will be significantly impacted by the operations of the Distribution System with high penetration of DER/ES, DR, and PEV.
- There are many transmission and distribution operation functions which should be coordinated and will need intensive information exchange

Matrix of Mutual Information Exchanges between Functions of Smart Transmission and Active Distribution Networks
Draft

Distribution finctions	Distribution System planning	Distribution load forecast	DER forecast and planning	DR forecast and planning	ES forecast and planning	PEV forecast and planning	DMS planning: DOMA	DMS planning IVVWO	DMS planning: MFR	DMS planning: FLIR	DMS planning: OMS	DMS planning: WMS	Modeling Transmission/Sub-Transmission	Modeling Distribution	Modeling Distribution	Modeling Distributed Energy	Modeling Distribution	Distribution Power Flow	Analysis of adequacy of	Analysis of reliability -	Power Quality Analysis	Analysis of the economic	Determining the dynamic	Determining the aggregated available	Determining the aggregated at the T&D buses	Determining the aggregated at the T&D	Intelligent Alarm Processing (IAP)	Integrated Volt/var/Watt	Fault location	Fault Isolation and Service	Multi-level Feeder	Distributed generation pre-	Demand response pre-setting	Electric storage enabling pre-	Distributed intelligence	Relay Protection Re-	Pre-arming of Remedial	Coordination of Emergency	Coordination of Restorative	Other	Operationally critical	Architurally critical	Semantically critical (Object Models)
Transmission Function	Planning functions												DOMA sub-functions (Situational Awareness)															Controlling functions															
1. **Normal operating conditions**																																											
a. Resource planning functions																																									X		X
b. System planning functions																																									X		X
c. Operation Planning functions																																											
i. Outage scheduling																																									X	X	X
ii. Day(s)-ahead operation planning																																									X	X	X
iii. Unit Commitment/Hydro-Thermo Scheduling																																									X	X	X
iv. Transaction scheduling																																									X		
d. Load forecasting functions																																											
i. System load forecast																																									X	X	
ii. Bus load forecast																																									X	X	X
e. Near real-time generation monitoring functions																																											
i. Reserve monitoring																																									X	X	
ii. Production cost monitoring																																									X	X	
iii. Evaluation of re-dispatch cost																																									X	X	X
iv. Other																																											
f. Near real-time and real-time generation control functions																																											
i. Economic Dispatch																																									X	X	
ii. AGC																																									X	X	
iii. Volt/var/Watt control																																									X	X	X
iv. Other																																											
g. Near real-time transmission monitoring functions (Wide Area Situational Awareness)																																											
i. Topology monitoring (incl. availability of controllable devices)																																									X	X	X
ii. Bus load modeling (include Load-to-Voltage and Load –to-Frequency dependences and load management capabilities)																																									X	X	X
iii. State estimation (with PMU)																																									X	X	X
iv. Dynamic limit monitoring																																									X	X	X
v. Network Sensitivity Analysis																																									X		X
Operationally Critical	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	x	X	X	X	X				
Architecturally critical													X	X	X	X	X	X			X	X	X	X		X		X	X	X	X	X	X	X	x	X	X	X	X				
Semantically critical (Object models)	X	X	X	X	X	X							X	X	X	X								X	X	X	X	X				X	X	X	x				X				

Matrix of Mutual Information Exchanges between Functions of Smart Transmission and Active Distribution Networks (Cont.)

Distribution finctions	Distribution System planning	Distribution load forecast	DER forecast and planning	DR forecast and planning	ES forecast and planning	PEV forecast and planning	DMS planning: DOMA	DMS planning IVVWO	DMS planning: MFR	DMS planning: FLIR	DMS planning: OMS	DMS planning: WMS	Modeling Transmission/Sub-Transmission	Modeling Distribution	Modeling Distribution	Modeling Distributed Energy	Modeling Distribution	Distribution Power Flow	Analysis of adequacy of	Analysis of reliability -	Power Quality Analysis	Analysis of the economic	Determining the dynamic	Determining the aggregated available	Determining the aggregated at the T&D buses	Determining the aggregated at the T&D	Intelligent Alarm Processing (IAP)	Integrated Volt/var/Watt	Fault location	Fault Isolation and Service	Multi-level Feeder	Distributed generation pre-	Demand response pre-setting	Electric storage enabling pre-	Distributed intelligence	Relay Protection Re-	Pre-arming of Remedial	Coordination of Emergency	Coordination of Restorative	Other	Operationally critical	Archituraly critical	Semantically critical (Object Models)
vi. Static contingency analysis																																									X	X	X
vii. Dynamic security analysis																																									X	X	X
• Angle stability																																									X	X	X
• Short-term voltage stability																																									X	X	X
• Frequency stability (Generation-load mismatch)																																									X	X	X
• Slowly developing voltage stability																																									X	X	X
viii. Cyber Security Contingency Analysis																																									X	X	X
ix. Intelligent alarm processing																																											X
x. Other																																											
h. Near-real-time transmission optimization functions																																											
i. Optimal power Flow (including load management means in distribution)																																									X	X	X
• Loss minimization																																									X	X	
• Cost of energy minimization																																									X	X	X
• Locational Marginal Price minimization (Congestion management)																																									X	X	X
ii. Security Constraint Dispatch																																									X	X	X
i. Real-time transmission control functions																																											
i. Distributed Intelligence control functions (localized control with overrides and arming)																																									X	X	X
ii. Close-loop combined OPF (including aggregated controls of means in distribution)																																									X	X	X
j. Post mortem analyses of transmission operations.																																									X		X
2. Emergency Operating Conditions *(including the DER/ES, Demand Response, and interrelationships between the transmission and automated distribution operations)*																																											
a. Protection functions based on local information																																									X		
b. Emergency control functions based on local information																																									X		X
c. Data gathering functions for post mortem analyses																																											
i. Event recording																																									X	X	X
ii. Transient processes recording																																									X	X	X
iii. Gathering static data on substation/generator level																																									X		X
iv. Gathering static data on generation, transmission and distribution system levels (includes DER)																																									X	X	X
v. Gathering static data on inter-utility level																																									X	X	X
vi. Gathering static data on customer level																																									X	X	X
Operationally Critical	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	x	X	X	X	X				
Architecturally critical													X	X	X	X	X	X			X	X	X	X		X		X	X	X	X	X	X	X	x	X	X	X	X				
Semantically critical (Object models)	X	X	X	X	X	X							X	X	X	X								X	X	X	X	X				X	X	X	x				X				

Matrix of Mutual Information Exchanges between Functions of Smart Transmission and Active Distribution Networks (Cont.)

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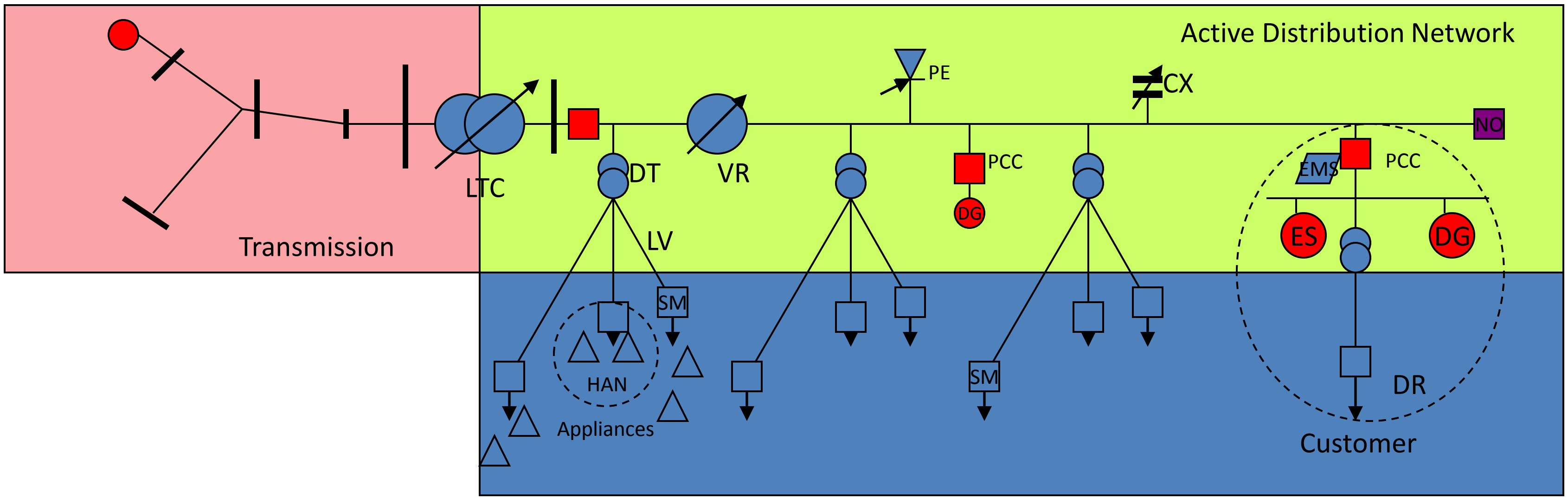
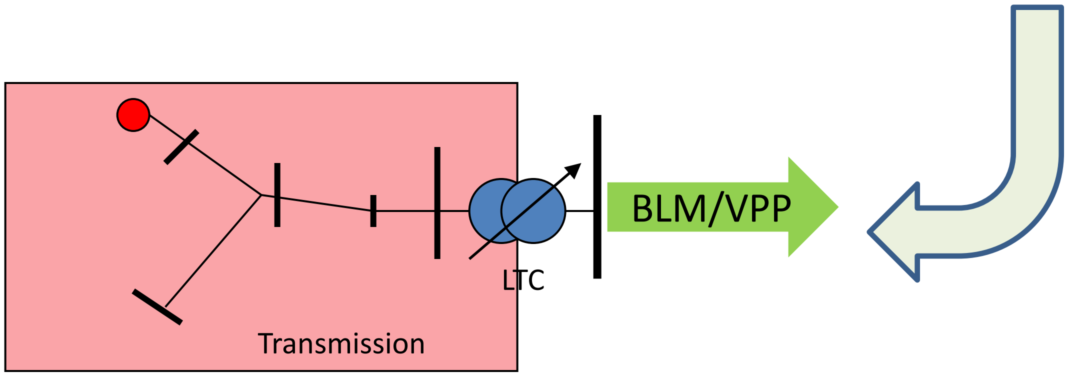
d. Post mortem analyzing functions on substation level																																								X		X
e. Post mortem analyzing functions on system level																																								X		X
f. Post mortem analyzing functions on inter-utility level																																								X		X
g. Near-real time monitoring function																																										
i. On substation/generator level																																								X		
ii. On generation, transmission and distribution system levels																																								X	X	X
iii. On inter-utility level																																								X	X	X
iv. On customer level in aggregated manner																																								X	X	X
h. Near real time pre-arming and re-coordination functions																																										
i. Relay protection																																								X	X	X
ii. Load-shedding																																								X	X	X
iii. Generator-shedding																																								X	X	X
iv. Fast generator starts based on operational parameters (angle, voltage, frequency, other)																																								X	X	X
v. Intentional islanding in transmission																																								X	X	X
vi. Intentional islanding in distribution																																								X	X	X
vii. System stabilizer																																								X	X	X
viii. Voltage, var, and power flow controlling functions																																								X	X	X
ix. Distributed generation pre-setting (Aggregated)																																								X	X	X
x. Demand response pre-setting (Aggregated)																																								X	X	X
xi. Electric storage enabling pre-setting (Aggregated)																																								X	X	X
xiii. Re-coordination of protection in distribution systems based on transmission requirements																																								X	X	X
xiv. Other																																										
i. Real-time remedial action functions																																										
i. Load-shedding																																								X	X	X
ii. Generator-shedding																																								X	X	X
iii. Fast generator starts based on operational parameters (angle, voltage, frequency, other)																																								X	X	X
iv. Intentional islanding in transmission																																								X	X	X
v. Intentional islanding in distribution (micro-grids) based on transmission requirements																																									X	X
vi. Distributed generation starts (Aggregated)																																								X	X	X
vii. Demand response enabling (Aggregated)																																								X	X	X
viii. Electric storage enabling (Aggregated)																																								X	X	X
ix. Transmission sectionalizing																																								X		
x. Voltage, var, and power flow control																																								X	X	X
xi. Other																																										
j. Real-time restorative functions																																										
i. Auto-synchronization																																								X		
ii. Restoration of shed loads																																										
• After under-frequency load shedding																																								X	X	X
• After under-voltage load shedding																																								X	X	X
• After special load shedding																																								X	X	X
iii. Reset of distributed generation																																								X	X	X
iv. Reset of Demand Response																																								X	X	X
v. Reset of electric storage																																								X	X	X
vi. Other																																										
Operationally Critical	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	x	X	X	X	X				
Architecturally critical													X	X	X	X	X	X			X	X	X	X		X		X	X	X	X	X	X	X	x	X	X	X	X				
Semantically critical (Object models)	X	X	X	X	X	X							X	X	X	X								X	X	X	X	X				X	X	X	x				X				

How to Exchange Information between T&D?

- It is unrealistic to expect that the monitoring and control of transmission operations will reach out to every device and every function in the distribution and customer domains.
- The end buses of the near-real time model of transmission operations will be the demarcation points between transmission and distribution domains.

Transmission Bus Load Model (TBLM)





It is suggested aggregating the capabilities and the dynamics of distribution operations into TBLM

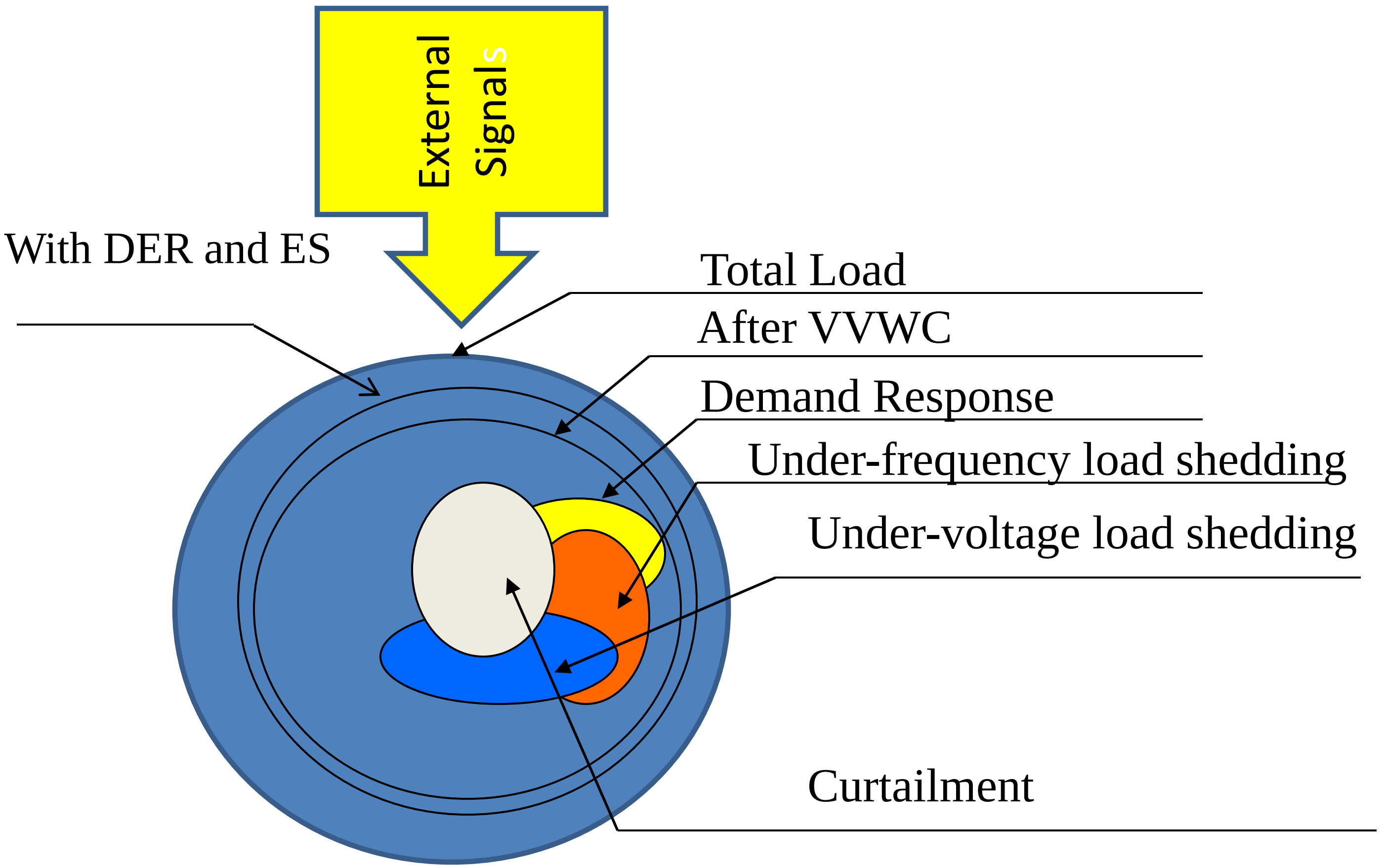
Transmission Bus Load Model (Cont.)

- The TBLM should represent the aggregated
  - near-real-time,
  - look-ahead (forecasted), and
  - available dispatchable loads in distribution

including
  - normal and
  - emergency

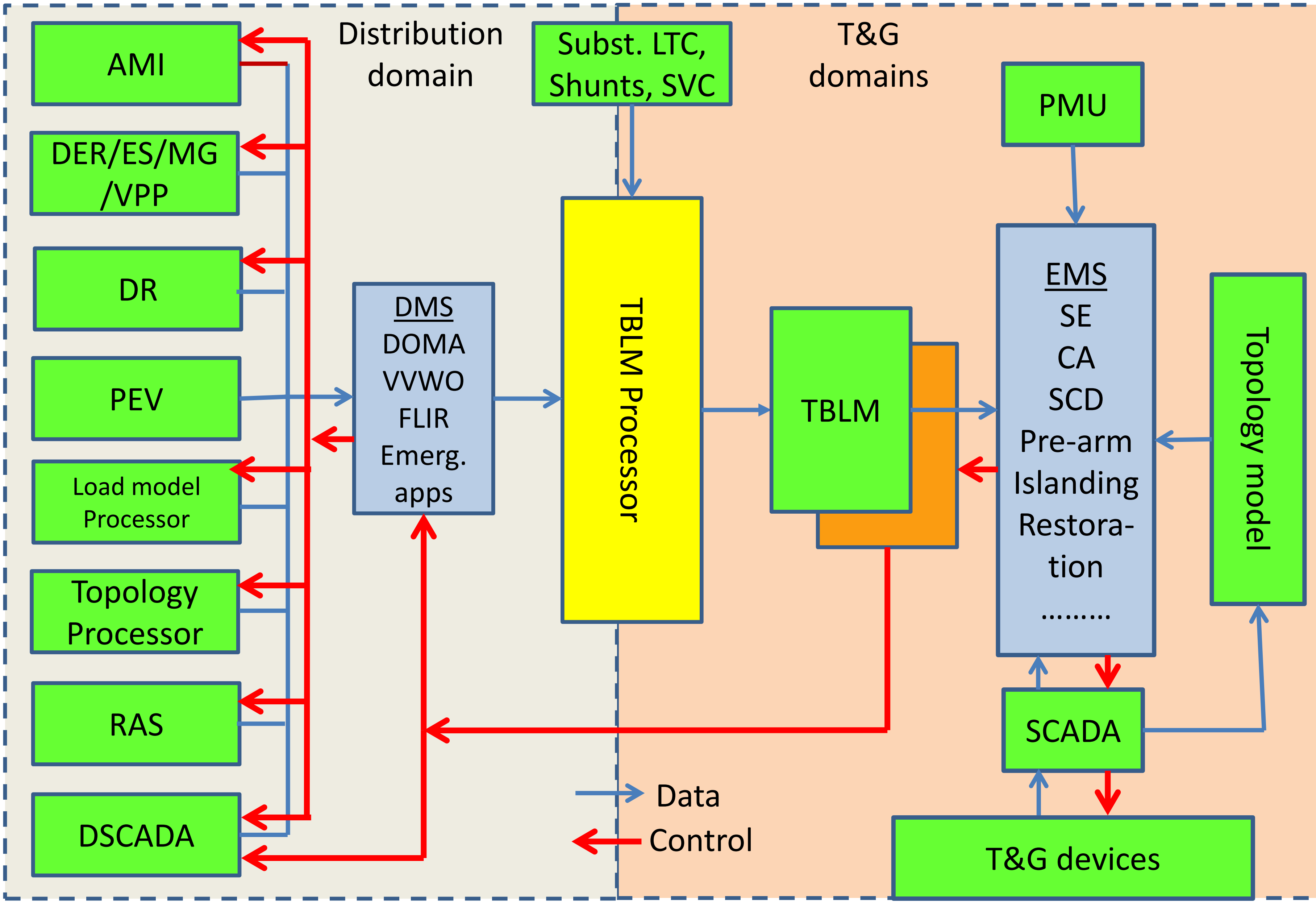
dependences of these loads on various impacting factors, such as
  - voltage,
  - frequency,
  - demand response controls,
  - price,
  - weather, etc.
- It should also represent the overlaps of different load management functions, which use the same load under different conditions.

Aggregated Bus Load Model



- This information should be generated by DMS and should be made available to EMS

Information and control flows



The Benefits of TBLM

- With such a dynamic model, updated by an Advanced DA application (mostly by DOMA) in near-real-time, the advanced EMS applications will be able to use adequate load models and additional aggregated controllable variables for the normal and emergency operations

The Priority of TBLM Use Case

- TBLM is the background use case for supporting transmission, distribution and customer cross-cutting Use Cases
- The use of the TBLM will provide the decomposition of the domains and, at the same time, preserving the cross-cutting interrelationships.
- If the use cases for transmission operations are developed without the interactions between T&D applications the use cases will not only be incomplete, - they will be inadequate for operations of the Smart Grid.

The Contents of the TBLM Use Case

- The Objective of the TBLM, including the coordination of the operations of the downstream active distribution network and the transmission operation applications
- The narrative of the TBLM use case
- The pre-conditions for the provision of the TBLM
- The actors involved in the TBLM
- The list and description of logical interfaces with the relevant attributes, like timing, accuracy, volume, etc.
- The diagram for the logical interfaces
- The sequential steps for periodic and for on-event operations
- The workload/messages for each interface.

Thank you!